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THE PLASTIC DEFORMATION OF ORE MINERALS PART 2. (CONCLUDED)

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ABSTRACT TO PART II.

In a previous installment,* experiments on the plastic characteristics of galena were described and the results explained in terms of atomic arrangement. In the present paper, the same methods are applied to sphalerite, chalcopyrite, and pyrrhotite.

Sphalerite deforms by gliding on $\{111\}$, but, contrary to Veit's conclusions, the character of the movement is that of secondary twinning, not translation. The lattice significance of twinning in sphalerite is briefly discussed.

Chalcopyrite was found to deform by translation on $\{111\}$. The translation direction was not obtained experimentally, but is predicted as $[110]$ from a consideration of the atomic arrangement. Continued deformation tends to reorient $[001]$ parallel with the load direction.

Pyrrhotite apparently deforms in a plastic way but experiments failed to give critical results.

No attempt was made to deform pyrite but probable geological evidence of its plasticity is drawn from the literature.

An hypothesis is presented to account for observed differences in plastic behavior. According to this hypothesis very pure minerals are expected to deform by translation while concentrated solid solution minerals are expected to deform by secondary twinning.

B. SPHALERITE

EXPERIMENTS.—After the writer had completed the experiments about to be detailed, he found that they had already been performed by Veit,²⁰ but with different results. Veit concluded that sphalerite deforms by translation on $\{111\}$ planes in? ²¹ $[11\bar{2}]$ directions. In what follows, it will be shown that sphalerite deforms by movement along $\{111\}$ planes, but that the character of the movement is that of twinning rather than translation.

A preliminary experiment was carried out to ascertain whether sphalerite would be amenable to deformation by Kick's method.

* *Am. Mineral.*, 13, pp. 1-17 (1928).

²⁰ Kurt Veit; Künstliche Schiebungen und Translationen in Mineralien, *Neues Jahrb. f. Min. Geol. u. Pal., Bl. Bd.* 45, pp. 125-128 (1922).

²¹ The question mark is Veit's.

The specimen used was one of the usual dark brown rounded crystals from Joplin (See Fig. 1-E). It could not be crystallographically oriented with certainty except by cleaving it and this was not attempted. It was placed in a copper tube 0.9 inches high and oriented as shown in Fig. 1-E. When so placed, its height was 0.55 inches. A load of 46,000 pounds was applied in 9 minutes. On removal of the matrix the crystal was found to measure 0.50 inches high along the previously measured direction. The color had changed to a lighter shade of brown, which is probably to be explained by the appearance of numerous small cleavage planes. The crystal was to all appearances as coherent as before deformation and could be repeatedly dropped without breaking. In addition to such of the total deformation (0.05 inches) as may have resulted from actual cleavage, much of it was certainly due to twinning or translation, for numerous, broad, offsetting bands, not noted previous to deformation, had been developed during the experiment. Examination with binoculars further revealed fine striae on perfectly transparent surfaces.

It should be stated that while the crystal was deformed when oriented as shown in Fig. 1-E, when the deformed crystal was re-photographed (Fig. 2-E) it was inadvertently placed in another orientation.

The foregoing preliminary experiment indicated that deformation could be accomplished in a plastic way by slip on some plane in sphalerite. It remained to determine (1) the plane of slip; and (2) the kind of deformation, whether true translation or twinning.

Accordingly, a second experiment was undertaken on sphalerite of known orientation. A cleavage piece of clear, transparent, yellow material from Santander, Spain,²² was selected and trimmed to a column 0.60 inches long, whose long axis was parallel to three of the dodecahedral cleavage planes. This was mounted in an alum matrix within a copper tube one inch high in such a manner that the axis of the column was parallel with the axis of the tube. This permitted the application of load normal to one family of octahedral planes and at slight angles to three other such families of planes.

A load of 46,000 pounds was applied in 18 minutes. After

²² It is interesting to note that Veit used sphalerite from the same locality. *Op. cit.*, p. 125.

removing the alum it was found that the test piece measured 0.55 inches long showing a total deformation of 0.05 inches. The specimen was no longer transparent but appeared somewhat cloudy. On handling it developed a parting plane normal to the length and therefore parallel to an octahedral plane. All the previously plane cleavage surfaces had become curved, and several of them had had developed on them very fine striations in three directions:

- (1) Along the long diagonal of a dodecahedral cleavage face.
- (2) Normal to one edge of the dodecahedral cleavage face; and
- (3) Normal to another edge of a dodecahedral cleavage face.

This fixes the planes along which slip takes place as the octahedral planes. On the octahedral parting, previously mentioned, there were also striations making angles of 120° with one another although only one set was well-developed. This is a further check on the identity of the slip plane.

Since the shearing component of a force is a maximum at an angle of 45° to the direction of application of the force, and zero normal to and parallel with it, it was at once apparent, that since a slip in sphalerite is indicated along octahedral planes, and since in the preceding experiment these planes were oriented, one normal to, and three making slight angles with the applied load, the maximum ease of deformation was probably not obtained. The optimum conditions for simultaneous slip on all four octahedral planes would be realized when the load is applied normal to the cube face, i.e. parallel with a crystallographic axis.

This was tried. A sphalerite cleavage dodecahedron (See Fig. 11-A) was ground and polished parallel to the dodecahedral cleavages until it had a height of 0.83 inches and widths, measured normal to dodecahedral faces, of 0.65 and 0.61 inches. This was mounted within a one-inch copper tube in an alum matrix and a load of 55,000 pounds applied in 15 minutes. On removal from the matrix it was found that the upper corner of the dodecahedron had come in contact with the brass end plate, and had made a deep impression thereon. The sphalerite was highly deformed, measuring only 0.58 inches high. Since the sides were considerably bulged, only an average set of measurements for widths could be taken—0.67 by 0.96 inches.

Part of the deformation had occurred, especially near the top, by actual fracture and fragmentation. A great deal of it took

place, however, by flow, since all uncleaved, clear faces were highly rounded and warped. Several dodecahedron edges were almost completely flattened and others had become much more acute. Megascopically it could be seen that a displacement of about 0.1 of an inch had taken place along a primary octahedral twin plane whose attitude had been noted before deformation.

Binocular observation revealed again the presence of multitudinous fine striae covering most of the faces. Again these were disposed as previously listed on page thirty-six. (See Figs. 11-A and 11-B). This confirms our previous observations and gives as slip planes $\{111\}$.

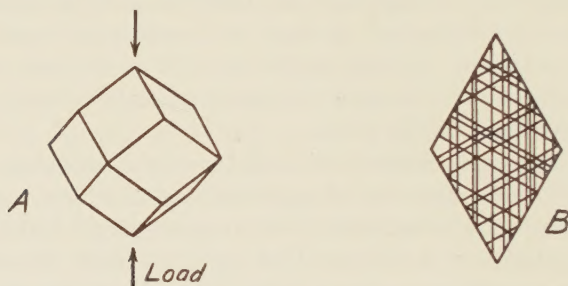


Figure 11.

- A. Sphalerite dodecahedron showing direction of loading in the third experiment.
- B. Detail of a single face of A, showing diagrammatically the directions of observed striations.

Up to this point the results are in entire accordance with those of Veit.²³ It is necessary to go further than the determination of the planes of movement however; it is imperative to know the character of the movement. This may be ascertained by etching tests. If simple translation occurs, all crystalline directions retain their original, mutual relations, and the crystal will yield a uniform etch. On the other hand if twinning occurs, the crystalline directions in deformed portions of the crystal will differ from those in undeformed portions, and etching on a random face will reveal the presence of twin bands.

To test out the nature of movement in sphalerite random faces were polished and etched with a dilute solution of potassium permanganate acidified with sulphuric acid. Twin bands were developed with startling clearness, showing beyond doubt that

²³ *Op. cit.*, p. 126.

deformation in sphalerite takes place, in part at least, by twinning on octahedral planes.

Several other experiments were undertaken to check these results and complete confirmation was obtained in each case. The experiments were substantially like the preceding ones and will not be detailed here.

Since twinning was observed on sphalerite from the same locality as that used by Veit, it must be concluded that this investigator overlooked twinning as a possible mode of deformation for this mineral.

THE MECHANISM OF SECONDARY TWINNING IN SPHALERITE.—Sphalerite crystallizes in the tetrahedral class of the isometric

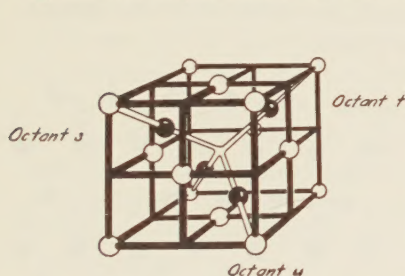


Figure 12. Unit cell of sphalerite. Either black or white balls may represent positions of zinc or sulphur atom centers.

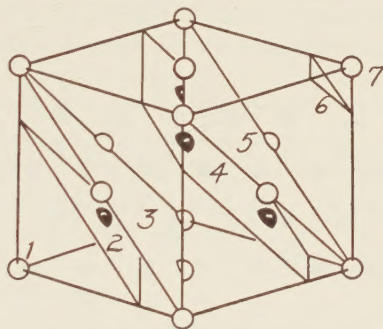


Figure 13. The seven octahedral planes of a unit cell of sphalerite. Plane 6 contains no atoms in the cell shown but includes atoms in adjacent cells.

system. Its atomic arrangement²⁴ consists of two, mutually interpenetrating, face-centered, cubic lattices, one for zinc and one for sulphur atoms. A unit cell, that is, the smallest possible atomic group having the symmetry of the entire crystal, and out of units of which the entire crystal may be constructed, is shown in Fig. 12. It is practically impossible to gain a conception of the entire lattice structure from a two-dimensional sketch of a single three-dimensional unit cell. With a model, however, it is possible to more easily visualize the lattice as a whole but a proper conception of the process of deformation is still difficult to obtain because of inability to move at will entire planes on a solid model. However, with a lattice model in view it is possible to reconstruct on glass

²⁴ International Critical Tables, vol. 1, pp. 339 and 342 (1926).

plates, the arrangement of atoms on any set of planes one pleases. By moving one plate with respect to another, the mechanism of deformation may be studied.

It is not the writer's intention to give here a complete treatment of secondary twinning in sphalerite. It is difficult to illustrate it by means of two-dimensional sketches, and it is beyond the scope of the present brief paper. Attention will be drawn only to three octahedral planes rather than the seven that are necessary to completely define the secondary twinning of a unit cell.

Fig. 13 shows the seven (111) planes in a single unit cell of sphalerite. To gain a complete conception of the atomic arrangement on these planes, a model of several unit cells must be examined. Plane 6, Fig. 13, for example, shows no atom, but atoms of adjacent cells are located in this plane.

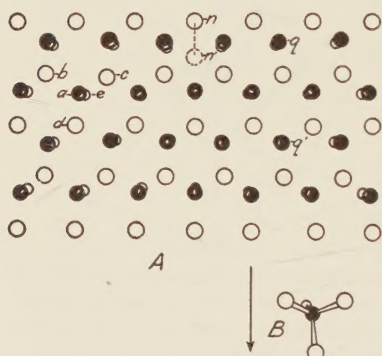


Figure 14. A—Perspective plan of octahedral planes 3, 4, and 5, Figure 13, looking in a $[111]$ direction. See text for further details. B—Orientation of any single octant in the planes shown in A.

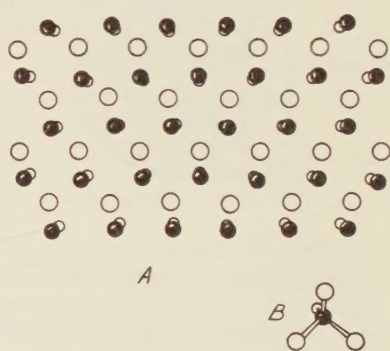


Figure 15. A—Same as Figure 14-A, but after twinning. See text for further details. B—The orientation of any single octant in the planes shown in A, after twinning. Compare with Figure 14-B, and note that a rotation of 180° of one about an axis normal to the plane of the paper, will bring it into coincidence with the other.

In Fig. 14-A a plan of planes 3, 4 and 5, Fig. 13, are shown. These give a complete picture of octants s , t , and u , Fig. 12, and of several other adjoining octants. Note that the black (zinc) atom, a , in the intermediate plane is equally distant from white (sulphur) atoms, b , c , and d , in the upper plane, and also from the white atom e , in the lower plane. This arrangement holds throughout

the figure, and a single octant exemplifying this is reproduced for convenience in Fig. 14-B. The arrow indicates a direction $[11\bar{2}]$. If, now, the entire upper plane is moved in the direction of the arrow until n occupies the dotted position n' with respect to the intermediate plane, and then both upper and intermediate planes are moved in the same direction past the lower plane until q occupies a position q' , the next black atom in line, the whole assembly of atoms assumes the disposition shown in Fig. 15-A. Note now that any black atom is again equally spaced between the surrounding white atoms. For convenience the atomic orientation of an octant is shown separately in Fig. 15-B. Comparison of Figs. 14-B and 15-B shows at once that the orientation of the octants has been changed, and that one could be made to coincide with the other by a rotation of 180° about an axis normal to the plane of the figure; in other words twinning has taken place on the octahedral plane.

The above, admittedly incomplete and brief explanation gives a preliminary conception of how secondary twinning on the octahedral plane takes place in sphalerite. Space is lacking to complete the discussion for all seven planes including a unit cell. Why twinning occurs rather than pure translation will be discussed on another page.

C. CHALCOPYRITE

EXPERIMENTS.—The writer knows of no published data concerning the experimental deformation of chalcopyrite.* The tests described below were, therefore, made to ascertain its behavior under differential pressure.

The accepted, probable, atomic structure of chalcopyrite is very similar to that of sphalerite. Although chalcopyrite is spenoidal

* It has come to my attention, as proof of this paper is received, that Mügge (*Neues Jahrbuch*, pp. 30–31, 1920) has investigated chalcopyrite. Subjecting minute crystals (1–3 mm. in size) from Burgholzhausen to pressures of 15,000 to 25,000 atmospheres, he obtained striae parallel to (111) which could be followed over several faces. In attempting to apply the usual Biegeleitung criterion for the determination of gliding direction (that the gliding direction is normal to the axis of bending) it was found that the crystals were irregularly bent, and therefore no gliding direction could be given. The character of the movement was found to be translation from the fact that reflections from the striae were variable, and not regular, as required by twinning. Furthermore, examination of thin splinters between crossed nicols in intense transmitted (?) light showed no twin bands. These data are in excellent agreement with the experimental results detailed in the present paper, independently obtained on material from another source and using quite different methods.

while sphalerite is tetrahedral, its axial ratio, $a:b:c$, is so nearly 1:1:1 (actually 1:1:0.985) that for practical purposes the chalcopyrite lattice may be visualized as a sphalerite lattice in which the basal planes of zinc atoms are replaced alternately by planes of iron atoms and planes of copper atoms. It would appear on casual consideration, therefore, that chalcopyrite should deform by twinning on sphenoidal planes very much as sphalerite deforms by twinning on octahedral planes. This reasoning acted as a guide in the orientation of chalcopyrite in the following tests.

Well-developed chalcopyrite single crystals of sufficient size for experimental work are difficult to obtain. For accurate work the crystal must be easily oriented and free from twinning. Since the axial ratio, $a:b:c$, is 1:1:0.985 the orientation is in itself difficult without goniometric measurements, and these measurements require flat bright faces.

The writer did not realize these ideal conditions but had to be content with experimenting on less desirable material. A crystal from French Creek was used in the first test (See Fig. 1-F). This had a longest dimension of approximately 0.7 inches before polishing. The predominant form was apparently the sphenoid while the corners were rounded by obscure rarer faces. All faces were dull and covered with growth lines, so the sphenoidal faces were ground and polished to facilitate subsequent metallographic study. Etching tests failed to reveal twinning.

Since the axial ratio of chalcopyrite so nearly approaches that of isometric crystals, the basal pinacoid could not be differentiated from the prismatic planes; hence while the specimen was oriented in a copper tube so that the load would be normal to some pinacoid, or prism plane, there is no means of knowing which one this was. When so oriented the specimen stood 0.50 inches high.

The crystal was embedded in alum within a copper tube 0.8 inches high and a load of 46,000 pounds applied in ten minutes. After deformation the height was still 0.50 inches, but all faces showed considerable curvature. The right hand point as shown in the photograph, Fig. 2-F, was bent down markedly. Several large and numerous small cracks were immediately apparent but the crystal was still very coherent.

Microscopic examination showed that all sphenoidal faces were covered with a network of minute striae parallel to sphenoid edges and intersecting at angles of approximately 60° and 120° (See Fig.

16). If the rough orientation of the crystal, above described, is correct, this can only mean that slip had occurred in some manner along sphenoidal planes. The presence of all three sets of striations on each of the four faces signifies the following with regard to direction of slip:

(a) That slip did not occur in a single direction parallel to one of the sphenoidal face edges. A consideration of Fig. 17 will show that if this did occur (slip of face *A* in the direction of the arrow, for example), the striations on face *B* in the direction shown by the dotted line, which can only be caused by a displacement of plane *A*, would be absent. This assumes, of course, that the polishing of the crystal was accurately done parallel to the natural sphenoidal faces, which is doubtful.

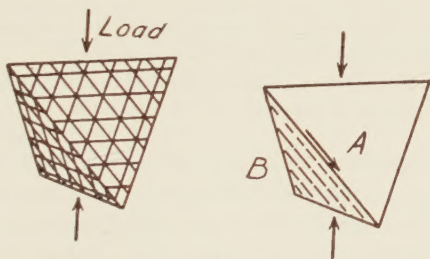


Figure 16. Diagram showing orientation of the chalcopyrite crystal deformed with respect to direction of loading. The intersecting lines on the sphenoid faces represent the directions of observed striations.

Figure 17. Expected condition if planes parallel to *A* slip in direction of arrow: no striations on face *B*.

(b) That slip of plane *A* took place alternately in directions parallel to *m* and to *n*, Fig. 18, that is, alternately parallel to one sphenoidal edge and another. Slip of *A* parallel to *m* would leave no trace on plane *B*, but slip parallel to *n* would leave such a trace or:

(c) That slip occurred in some other direction; if plane *A*, Fig. 19, for example, slipped in the direction shown by the arrow, it would leave striations on all other faces.

It would, indeed, be remarkable if possibility (a) were true. If the sphenoidal edge is the slip direction, and the specimen symmetrically loaded there is no apparent reason why some *A* planes should not slip in direction *m* and some in *n*, Fig. 18. There is precedent for alternate slip of this sort as shown by the writer's experiments on galena.

It is important to discover whether the slip indicated involved twinning or pure translation. There is reason to suppose, from the similarity of atomic arrangements and experimentally determined planes of atomic movement, that chalcopyrite should deform by secondary twinning as does sphalerite, rather than by pure translation.

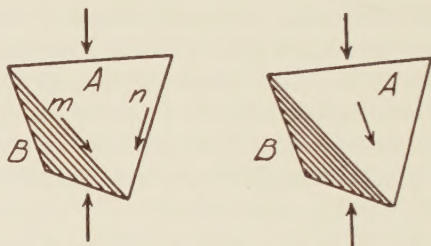


Figure 18. Expected conditions if planes parallel to A slip alternately in directions *n* and *m*: striations parallel to *m* produced on face B.

Figure 19. Expected condition if planes parallel to A slip in the direction of the arrow: striations produced on face B.

To test this supposition etching tests were very carefully made with a dilute potassium permanganate solution acidified with sulphuric acid and also with a saturated solution of potassium dichromate acidified with sulphuric acid. Before the reagent was applied to the deformed specimen, in each case a drop was applied to a polished section of twinned chalcopyrite as a blank test. Each blank test showed differential etching of twin bands on the chalcopyrite known to be twinned. The deformed test specimen was etched on numerous polished surfaces of known and random orientations but every etching test failed to reveal the least trace of twinning.

In order to check these results another chalcopyrite crystal was deformed with conditions the same as those in the first deformation test. Again negative results were obtained on etching numerous polished surfaces. The accordance of etching evidence seemed to disprove entirely the possibility of twinning in deformation of chalcopyrite and to determine the type of movement between {111} planes as pure translation.

THEORETICAL CONSIDERATIONS.—Assuming that the accepted, probable, crystal structure of chalcopyrite is the correct one, it is easy to see why the mineral should deform by translation on sphenoidal planes. In discussing the flow of galena certain general

principals were detailed relatively to the possibility of true translation: slip must take place in a direction parallel to lines of like charged atoms.

Attempting to apply these conditions to the chalcopyrite lattice one is confronted with the inability to determine chemically the charge of the iron atoms with respect to the copper atoms. Lattice considerations, however, because of the similarity of chalcopyrite and sphalerite structures, compel belief that the iron and copper atoms bear like charges. Hence the lines of similarly charged atoms may consist of:

- either (a) entirely copper or entirely iron atoms;
- or (b) alternating iron and copper atoms.

Alignment (a) is found in $[110]$ directions. A conception of the atomic arrangement may be gleaned from Fig. 20. The lines show traces of pairs of first order planes. Note that alternate pairs of (111) planes have the greatest spacing. Hence it follows that chalcopyrite might be expected to deform by translation on sphenoïd planes along a $[110]$ direction.

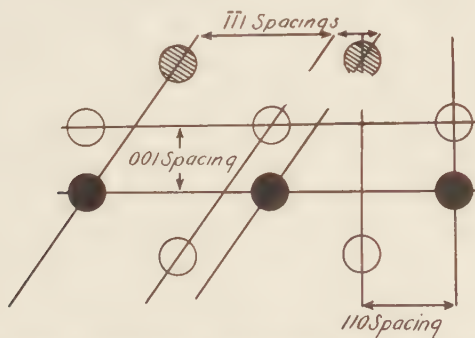


Figure 20. Atomic arrangement of chalcopyrite looking along a $[1\bar{1}0]$ direction. The dots are end views of rows of identical atoms. The white dots represent atom centers of sulphur; black, copper; gray, iron. The lines show traces of (001) , (110) , and $(\bar{1}\bar{1}1)$ planes. Note that there are two $(\bar{1}\bar{1}1)$ plane spacings. Slip occurs along those alternate pairs of $\{111\}$ planes of greater spacing.

Arrangement (b) is found along $[011]$ directions. Except for alternation of copper and iron atoms and inappreciable discrepancies in spacing, the atomic rows are the same as shown in Fig. 12. From speculative considerations, slip should occur with less ease along these lines since the atomic volumes of iron and copper are different. A plane containing iron and copper, because of this

difference in volumes, would be a rougher plane than a plane containing iron alone or copper alone. Hence it might be expected to offer greater atomic friction to movement of the adjacent sulphur plane than would a plane containing only one atomic species.

The foregoing discussion explains the translation along spheroïdal planes in chalcopyrite. It fails to explain why the sphalerite lattice deforms by secondary twinning while the closely related chalcopyrite lattice deforms by pure translation. This will be discussed on another page.

REORIENTATION PHENOMENA.—As has been shown in the case of galena, a reorientation is experienced by a randomly oriented crystal subjected to plastic deformation. Without again detailing the demonstration, it can be seen that if a chalcopyrite crystal is deformed it will approach an equilibrium position such that one of the pinacoidal planes is oriented normal to the direction of the applied force.

D. PYRRHOTITE

No data exists, to the writer's knowledge, on the experimental deformation of pyrrhotite. For this reason it seemed desirable to make a few tests on this mineral using Kick's method.

A specimen from Ontario, Canada, was secured which contained a single anhedral crystal of pyrrhotite having the approximate dimensions of 2 by $\frac{3}{4}$ by $\frac{3}{4}$ inches. The crystal reposed in a matrix consisting chiefly of a large oligoclase crystal. In addition this specimen contained a large piece of glassy quartz, some coarse calcite, a little chalcopyrite and some undetermined, soft, galena-grey mineral with octahedral parting or cleavage, all in contact with the pyrrhotite. On the oligoclase there was also a large piece of some amphibole. These associated minerals are mentioned to give some idea of the origin and hence composition of the pyrrhotite.

A small piece of pyrrhotite was broken off, ground and polished on two sides parallel to the basal parting and on six other sides at right angles to these. The crystallographic orientations of these six last mentioned surfaces were unknown except that they must be random faces in a prismatic zone. The orientation was checked with the aid of the polarizing metallographic microscope. Using crossed nicols the basal planes were dark in all positions of rotation and the six vertical faces showed the usual color changes in a half rotation of the stage.

Etching tests proved that the pyrrhotite was untwinned. However, the single crystal block was found to contain several other minerals as microscopic inclusions. In a calcite veinlet cutting through the center of the block in a plane perpendicular to the base an unidentified whitish mineral, resembling marcasite, but showing strong polarization colors, was noted. Throughout the pyrrhotite two minerals were disseminated in small specks: pentlandite, and another, somewhat lighter than pyrrhotite. On the surface polished in the prismatic zone these could be seen arranged in streaks parallel to the basal parting.

Careful measurements were taken and appropriate sketches made before the deformation tests. These will not be detailed in view of the negative results obtained, except to note that the pyrrhotite plate approximated about one-half an inch across the basal faces and was about one-quarter of an inch thick.

Since pyrrhotite twins on the pyramid ($10\bar{1}1$), an attempt was made in the first experiment to ascertain whether this mode of twinning could be produced as a result of deformation. Accordingly the specimen was oriented in the tube with its basal planes parallel to the tube axis. Thus the load would be applied along a basal plane and would have strong shearing components along the pyramidal planes.

Alum was employed as the embedding medium, and a copper tube one inch long was used. This allowed a clearance of about a quarter of an inch between the pyrrhotite test piece and the end plates. A load of 44,000 pounds was applied in 12 minutes. On dissolving away the alum it was found that the pyrrhotite had not reached the end plates during the test. Nevertheless it had cracked in several pieces without any visible sign of plastic deformation. The pieces, on polishing and etching, failed to reveal any sign of twinning.

Since no twinning occurred in this experiment another was devised to test the character of the basal plane as a glide plane. For this purpose another piece of pyrrhotite was polished, examined, measured and mounted as before but this time with the basal planes making an angle of 45° with the direction of application of the load. A three-quarters inch tube was used and alum again employed as an embedding medium. A load of 49,200 pounds was applied in 27 minutes. On solution of the alum it was found that the specimen had not made contact with the end plates, and further, that

no deformation was to be seen. Etching tests proved the absence of twinning.

From the results of these experiments it was thought that sufficient pressure had not been applied. Alum deforms so much more readily than pyrrhotite that it merely flows about this harder body on application of load. An experiment was, therefore, arranged in which the pyrrhotite could come in contact with the end plates. The specimen from the foregoing experiment and the large fragment from the first experiment were set one on top of the other in a three-quarters inch tube, one lying on its base, the other with the basal plane inclined to the axis of the load.

A load of 54,000 pounds was applied in 10 minutes. Removal of the test pieces showed that they had been in contact with the end plates and had received, therefore, a pressure much greater than the alum alone could transmit. The upper smaller piece had left a distinct imprint on the lower piece, and where it had overlapped, had been forced downward past the lower pyrrhotite block. Examination with binoculars showed that this deformation had taken place both by cracking and true flow. The latter was revealed by the presence of several uncracked but warped surfaces. Upon one of these were a number of fine striations parallel to the trace of the basal parting on this face, and resembling closely slip- or twin-bands.

From the above it will be recognized that there is some presumptive evidence for flow of pyrrhotite by gliding. However, since the striations were few and noted only on one face, the attitude of the possible glide plane cannot be definitely known. Further experimentation was curtailed by the immediate lack of suitable single crystals of pyrrhotite.

E. PYRITE

Adams²⁵ attempted to deform pyrite by the method described. He embedded a fragment of a pyrite cube in alum with the edge of the cube upward and applied a load of 43,000 pounds in 17 minutes. During the test the pyrite came in contact with the end plate which, therefore, transmitted a large part of the load. On removing the crystal by solution of the alum he found that it had been crushed and powdered "without showing any trace of plastic deformation."²⁶ It seemed useless to repeat the experiment with the same

²⁵ Frank D. Adams, *Jour. Geology*, 18, p. 509 (1910).

²⁶ Veit was also unsuccessful in attempting to deform pyrite. *Op. cit.*, p. 146.

method and apparatus so no further experimental work was carried out by the writer. However, it seems probable that even this hard mineral might be made to flow by employing a method which would afford much greater lateral support, such a method, for example, as was later used by Adams and Coker²⁷ in the study of the flow of marble.

The data given by Adams are sufficient, however, for some conclusions. When pyrite is subjected to a load transmitted by some hard mineral with which it is in contact, and embedded in material which flows with the same readiness as alum we should expect it to suffer crushing. Roughly speaking, galena flows with the same order of ease as alum, as shown by the experiments on galena in which this mineral readily deformed in an alum matrix without touching the end plates of the containing apparatus. Hence, in nature, if pyrite is found in a deformed galena deposit and in contact with quartz, for example, we would expect it to crush rather than to flow. That this is indeed the case is illustrated in the Slocan²⁸ and Coeur d'Alene²⁹ districts.

Whether or not pyrite will actually flow when embedded in a more resistant matrix is a subject which deserves experimental attention. Some geological evidence for *possible* flow of pyrite enclosed in a matrix of sphalerite and chalcopyrite (which are more resistant to flow than galena) is to be found in the ores of Rammelsberg described by Lindgren and Irving,³⁰ although these writers are inclined to interpret the elongated pyrite nodules as crushed residuals.³¹

DEFORMATION BY SECONDARY TWINNING

As noted on previous pages, the simple lattice theory of translation, while satisfactory for observed deformation by translation, fails to explain the unlike deformation behaviors of the struc-

²⁷ Frank D. Adams and Ernest G. Coker; An experimental investigation into the flow of rocks, *Am. Jour. Sci.*, (4) 29, pp. 465-487 (1910).

²⁸ W. L. Uglow; Gneissic galena ore from the Slocan district, B.C., *Econ. Geol.*, 12, 643-662 (1917).

A. M. Bateman; Notes on silver-lead deposits of Slocan district, B.C., Canada, *idem*, 20, 562 (1925).

²⁹ W. A. Waldschmidt; Deformation in ores, Coeur d'Alene district, Idaho, *idem*, 20, 577 (1925).

³⁰ W. Lindgren and J. D. Irving; The origin of the Rammelsberg ore deposit, *idem*, 6, 311 (1911).

³¹ *Op. cit.*, p. 313.

turally similar chalcopyrite and sphalerite lattices. By taking into account the impurities present, however, the reason for the apparently anomalous twinning of sphalerite becomes clear.

All crystals, leaving out of consideration any mechanical admixtures, are impure. Mineral crystals particularly, seldom more than closely approximate their theoretical formulae. The impurities present must form an inherent part of the orderly internal atomic arrangement although it is usually only when they are appreciable in amount that they receive recognition by the designation "solid solution." Because of the differing atomic volumes of the solute and solvent atoms (or, in certain cases, groups of atoms) structural distortions are certain to mark the presence of foreign atoms in the lattice, as shown by Rosenhain.³² In the case of rather concentrated solid solutions, the foreign atoms distort the perfect flatness of translation planes causing them to become warped surfaces. Consequently, as Rosenhain has pointed out,³³ translation is more difficult in impure than in pure crystals due to the locking action of adjoining, distorted planes. Since translation, to become even microscopically visible, involves a localized slipping between planes for distances of many atom diameters, it may completely escape detection in concentrated solid solutions, because the extent to which translation takes place must be highly restricted in these greatly distorted lattices. On the other hand, deformation by secondary twinning involves a completely distributed³⁴ interplanar adjustment in the order of only one atom diameter, as shown in the case of sphalerite, and the resulting deformation is immediately apparent by etching due to the changed lattice orientation. Thus a very pure crystal would be expected to deform by translation while an impure one, having distorted planes upon which extensive slip would be attended by great friction, would be expected to deform by secondary twinning.

It is noteworthy that chalcopyrite when not associated with cubanite, is a very pure mineral, while sphalerite is notoriously impure, dark sphalerite containing from 1 to 18 per cent of iron in

³² Walter Rosenhain; Solid solutions, *Trans. Am. Inst. Min. Met. Engs.*, 69, pp. 1011-1017 (1923).

³³ *Op. cit.*

³⁴ That is, the same relief of pressure which when accomplished by translation of a few planes for long distances, can also be accomplished by a slight adjustment distributed on all planes throughout the entire crystal.

addition to appreciable quantities of other foreign metals.³⁵ In confirmation of this it is found that in cases where cubanite is present as an unmixed structure in chalcopyrite, the latter also displays polysynthetic twinning on etching.³⁶ Cubanite and chalcopyrite are known from Schwartz's investigations³⁷ to form solid solutions. The inference is that the presence of cubanite in the chalcopyrite lattice before unmixing (or possibly its residue after partial unmixing) so distorts the lattice that twinning but not translation is possible.

Alling³⁸ notes that microcline (a solid solution mineral), untwinned before thin section grinding or before pulverizing, deforms by twinning during these operations, and that twinned microcline can be used as an indication that the mineral has been subjected to the action of excessive compressive forces, as for example, in the vicinity of a fault. Among the other solid solution minerals to which secondary twinning is attributed may be mentioned: plagioclase,³⁹ garnet, pyrrhotite, pyroxene, calcite, and dolomite. These few examples tend to confirm the supposition that impurities engender secondary twinning rather than translation on deformation.

The writer takes this opportunity to gratefully acknowledge the aid given by Doctor W. H. Newhouse during the experiments.

³⁵ Dana's System, p. 61, New York (1914).

³⁶ The ore from the Pike Hill Mine, Corinth Vermont, shows this very well. Cubanite is present as laths cutting across twin bands in the chalcopyrite.

³⁷ G. M. Schwartz; Intergrowths of chalcopyrite and cubanite, *Econ. Geol.*, **22**, pp. 44-61 (1927).

³⁸ Harold L. Alling; The mineralography of the feldspars, *Journal of Geology*, **29**, pp. 209-210 and 275-276 (1921), *idem*, **31**, pp. 357-358 (1923).

Strictly, Alling believes that untwinned *orthoclase* is changed by pressure to twinned *microcline*.

³⁹ Harold L. Alling; *idem*, **31**, p. 357 (1923).

ISOMORPHOUS RELATIONS OF MgSiO_3 AND AlAlO_3 IN SILICATESA. N. WINCHELL, *University of Wisconsin.*

There seem to be numerous examples of a simple isomorphous relationship between MgSiO_3 and AlAlO_3 in silicates. Even in the simple molecule, MgSiO_3 , the molecule AlAlO_3 may apparently enter isomorphously to a limited extent, such as, about 5 per cent in enstatite and 10 per cent or more in anthophyllite. In certain larger molecules, such as diopside, $\text{CaMgSi}_2\text{O}_6$, and the equivalent amphibole molecule, AlAlO_3 seems to be miscible to about the same extent. According to experimental work by E. Fixek¹ in the laboratory of Professor Doelter, AlAlO_3 may enter $\text{CaMgSi}_2\text{O}_6$ (as well as MgSiO_3) isomorphously to as much as 25 per cent. In analyses of natural augite and hornblende the tenor of alumina not combined with alkalis rarely exceeds 10 per cent, but apparently may reach 15 per cent in very exceptional cases. In still larger molecules such as akermanite, $\text{Ca}_2\text{MgSi}_2\text{O}_7$, alumina may replace the entire tenor of MgSiO_3 , thus leading to gehlenite, $\text{Ca}_2\text{Al}_2\text{SiO}_7$; this fact has been established beyond question by the experimental work of Ferguson and Buddington² at the Geophysical Laboratory. In another large molecule, namely antigorite, $\text{H}_4\text{Mg}_3\text{Si}_2\text{O}_9$, the theory of Tschermak, which has long been accepted by mineralogists, generally, requires that AlAlO_3 replace MgSiO_3 to form a (continuous?) series to the mineral amesite, $\text{H}_4\text{Mg}_2\text{Al}_2\text{SiO}_9$, of the chlorite group. The writer has recently argued that the same kind of variation occurs in the micas,³ and his views on this point have been called in question by Hallimond.⁴ Of course, it is not certain that there is the same kind of variation in the micas that seems to be present in pyroxenes and amphiboles, is generally accepted in chlorites and is certainly present in melilites, but if it does not occur in micas it would seem necessary to re-examine the evidence for it in the other groups. Therefore the determination of the question as to the micas is of considerable importance.

¹ Doelter: *Hdb. Mineralchem.*, II, 1, 1914, p. 568.

² *Am. Jour. Sci.*, CC, 1920, p. 141.

³ *Am. Jour. Sci.*, CCIX, 1925, pp. 309-328 and 415-431; *Am. Mineral.*, XII, 1927, pp. 267-279.

⁴ *Mineral. Mag.*, XX, 1925, pp. 305-319 and XXI, 1926, pp. 25-34; *Am. Mineral.*, XII, 1927, p. 413.

It is obvious that analyses of pure muscovite have no bearing on the question since every one assigns the formula $H_4K_2Al_6Si_6O_{24}$ to that mineral. The problem is to determine the composition (or the mode of variation from muscovite) of the micas which Tschermak called phengites and described as characterized by a small optic angle and a high tenor of silica. A study of analyses of micas is sufficient to show that phengitic micas are also characterized by the presence of an appreciable tenor of MgO or (Fe, Mn)O or both. According to Hallimond's theory this RO replaces Al_2O_3 , while according to the writer's theory $MgSiO_3$ replaces $AlAlO_3$ in the muscovite formula.

The writer⁵ has previously called attention to the fact that Doelter⁶ gives twenty-one analyses of phengite and that not one of these analyses contains enough $K_2O + Na_2O + Ca_2O_2$ to satisfy the requirements of the theory of Hallimond. A few of them do contain enough alkalis to meet the requirements of the writer's theory, but most of them are old and probably inaccurate. It seems best, as suggested by Hallimond, to disregard these entirely.

The writer⁵ also cited three modern analyses of phengitic micas, as rich in the phengite molecule as he could find, and showed that these correspond well with his theory. This evidence is clearly not sufficiently convincing, since Hallimond⁷ disregards it entirely and argues that "an ideal test of the theories would consist in a series of recent analyses made by the same observer, upon materials selected with care and graduated from pure muscovite up to the highest available content of MgO"; he adds that "fortunately a series of this kind is available in the well-known research by Kunitz." The writer agrees that this plan has certain advantages which make it worthy of attention. It is obvious that any test of the writer's theory must be based upon computations which are in harmony with that theory. This point was evidently overlooked by Hallimond when he made the comment that such a study of the analyses of Kunitz indicates "no trace whatever of a progressive diminution in $K_2O:SiO_2$ as the magnesia increased." As a matter of fact the analyses of Kunitz⁸ lead to the results expressed in Fig. 1, when they are plotted on two coordinates, namely K_2O

⁵ *Am. Mineral.*, XII, 1927, p. 272.

⁶ *Hdb. Mineralchem.*, II, 2, 1917, pp. 418-431.

⁷ *Am. Mineral.*, XII, 1927, p. 413.

⁸ *N. Jahrb. Min., Beil. Bd.* L, 1924, p. 365.

+Na₂O+Ca₂O₂ and MgO+FeO+MnO as required by the theory of the writer, each coordinate assuming that the analysis is calculated to the condition SiO₂+TiO₂=600, as suggested by Hallimond. In the diagram the numbered points representing the analyses should lie along the horizontal line to confirm the theory of the writer. Nearly all of these analyses contain too much alkali to agree with either theory, but it is clear that their average position is along a line inclined at least as much as required by the theory of the writer.

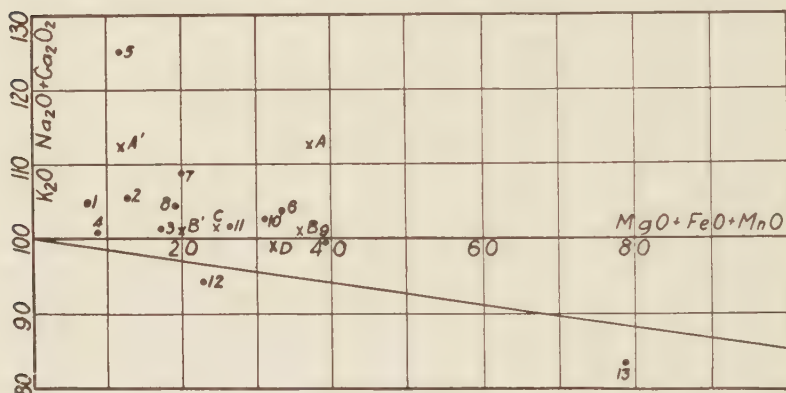


Figure 1. Relations between K₂O(+Na₂O+Ca₂O₂) and MgO(+FeO+MnO) in the muscovite system, assuming SiO₂+TiO₂=600, as shown by the data of Kunitz (*N. Jahrb. Min., Beil. Bd.*, L, 1924, p. 365). Nos. 1-11 = Kunitz analyses 1-11 (*op. cit.*, p. 376); No. 12 = Kunitz analysis 12, (*op. cit.*, p. 412); No. 13 = Kunitz analysis (*op. cit.*, p. 383), his Fe₂O₃+FeO taken as FeO.

Of course this test is just as unfair to Hallimond's theory as his method of calculation is to the writer's theory. However, if the analyses are located by calculations based on the theory of Hallimond the only ones which would change position *materially* are numbers 5 and 7, which would then appear at the points A and B respectively. The average position of the points is then approximately along a horizontal line *with the very important exception of number 13*.

The difference in the two theories, so far as the method of calculation is concerned, is that Hallimond's theory requires that the CaO shall be included with MgO, while the writer's theory requires that it shall be included with the alkalis. Jakob⁹ has very recently con-

⁹ *Zeit., Kryst.*, LXII, 1925, p. 443.

cluded, after making many analyses of very carefully purified micas, that they contain no lime whatever, and that any lime found is due to impurities in the mineral sample or in the reagents used. If this is true, then analyses 5 and 7 belong at the points A' and B' respectively, and the average position of the points is then clearly along an inclined line similar to that required by the writer's theory.

There is one way to use the analyses of Kunitz to test the question which is fair to both theories. There are only two of his analyses that contain important amounts of lime. If these two analyses (Nos. 5 and 7) be removed from the diagram entirely, the remaining points¹⁰ show clearly the "progressive diminution in the $K_2O:SiO_2$ " ratio with increase of magnesia which Hallimond failed to find.

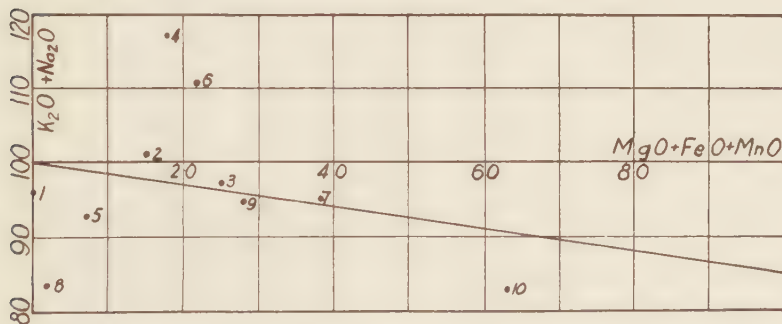


Figure 2. Relations between $K_2O(+Na_2O)$ and $MgO(+FeO+MnO)$ in the muscovite system, assuming $SiO_2+TiO_2=600$, as shown by the data of Jakob (*Zeit. Kryst.*, LXII, 1925, p. 443). Nos. 1-10=Jakob's analyses 9-18 in regular order.

On account of this difficulty as to the proper way to calculate the lime in order to test the two theories it is fortunate that there is another "series of recent analyses made by the same observer, upon materials selected with care and graduated from pure muscovite to the highest available content of MgO " which includes no lime whatever in any of the analyses. This is the series of Jakob.⁸ Calculations of the analyses of this series lead to the

¹⁰ Of the eleven analyses remaining, six contain no lime whatever, three (1, 4 and 9) contain less than 0.2 per cent, and two (8 and 11) contain about 0.4 per cent. Calculated by Hallimond's method analysis 8 appears at C and analysis 11 at D.

diagram¹¹ shown in Fig. 2. Some of the points on this diagram vary from the average position more than is to be expected, but, nevertheless, the mean position seems to be along a line inclined at least as much as required by the writer's theory.

The writer is gratified to learn from Dr. Hallimond's recent discussion¹² that he is ready to admit the presence of "small quantities of other molecules" in micas not having the constant ratio $K_2O:SiO_2=1:6$. The only question seems to be, then, whether these "small quantities" can become large quantities in some cases. It seems to the writer more reasonable to accept a small variation in the $K_2O:SiO_2$ ratio rather than to assume a large variation in that ratio such as would be necessary to explain the results of some analyses if one is to cling to the idea that the main part of every analysis consists of mica having the 1:6 ratio. If the $K_2O:SiO_2$ ratio varies only a little from 1:6, then, obviously, large quantities of such molecules must be present to explain the results of some analyses.

The chief theoretical difficulty with the theory of Hallimond that MgO replaces Al_2O_3 in muscovite is that it requires one to believe that one atom of magnesium may take the place of two atoms of aluminum, and that one atom of oxygen may take the place of three atoms of oxygen, in the crystal space lattice. The chief practical difficulty with the same theory is that it is not in harmony with the modern analytical data on the composition of micas of the muscovite series.

THE BLACK HILLS MINERAL REGION

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INTRODUCTION

There is probably no other region 100 miles long and 50 miles wide that contains such a wealth of geological and mineralogical interest as the Black Hills of South Dakota. The pegmatites in the region around Harney Peak have yielded a number of rare minerals, some being new species, and large amounts of many more common ones. There too are found the largest known crystals of

¹¹ An error must be corrected: in the writer's former article on the micas (*Am. Mineral.*, July, 1927), the "86 molecules" mentioned in the fourth line from the bottom of page 272 should read "91 molecules."

¹² *Am. Mineral.*, **XII**, 1927, p. 413.

spodumene. Exceptionally large crystals and masses of other minerals are also abundant. Commercial production from the Harney Peak region has included mica, the lithium minerals—spodumene, amblygonite, and lepidolite—beryl, columbite-tantalite, wolframite, galena, gold and silver minerals. Cassiterite has been exploited but has not proved of much value to date.

In the northern portion of the Black Hills gold has been the principal mineral of value but ores of silver, lead, zinc, tungsten, and gypsum have also been produced. The importance of the gold production has been largely due to the Homestake mine, the largest gold mine in the United States. This mine has produced almost without interruption since 1876 and has a record of over \$200,000,000 production.

Since the Black Hills were first opened to settlement in 1876 the varied mineral deposits have excited great interest. In fact it was the discovery of gold in 1874 which caused the opening of the area, and the resentment of the Indians over the loss of this fine hunting ground led to the Custer Massacre on the Little Bighorn River to the northwest in Montana on June 25, 1876.

LOCATION

The Black Hills are situated in the extreme western part of South Dakota and extend somewhat into northwestern Wyoming. The region is served by the Chicago, Burlington and Quincy Railroad, the Chicago and Northwestern and a branch of the Chicago, Milwaukee and St. Paul. The region may be reached by way of Omaha, Chicago, Minneapolis, or Denver. Several good highways now approach the Hills and tourists visit them in increasing numbers each year. Suitable accommodations are available at many points and good roads lead to practically all of the mines and other points of mineralogical interest. The most convenient way to visit the points noted below is by auto, but the writer has made several trips to the region and used an auto but little, depending on trains, busses, and walking. Detailed directions and maps may be obtained at the hotels and tourist bureaus making it very easy for anyone to find the deposits. The maps prepared by Ziegler¹ are of great assistance. Anyone visiting the region will find it convenient to transfer the data from Ziegler's map to the topographic sheets of the region. A recent bulletin by O'Harra and

¹ Ziegler, V.; *S. D. School of Mines, Bull.* **10**, (1914).

Connolly² shows the location of most deposits of the Harney region on a key map, with notes on many deposits and the minerals found in them. The list of mineral localities on pages 94 and 95 is particularly useful to the collector.

GENERAL GEOLOGY

The geology of the Black Hills has been described in general and in detail in a great many papers which are listed in a bibliography issued by Dr. O'Harra.³ The main part of the region is well described in the recent folio by Darton and Paige.⁴ Previous reports by O'Harra,⁵ Darton,⁶ Irving,⁷ and Jaggar⁸ are especially comprehensive.

The Black Hills are the farthest east outlier of the Rocky Mountain system with which they connect structurally by the Laramie mountains to the south. Physiographically they are not hills but mountains. The average elevation of surrounding plains is about 3000 feet while Harney Peak reaches an elevation of 7242 and other peaks in various parts of the region reach 6500 feet. Terry Peak not far from Lead in the northern part attains an altitude of 7071. The region is not lacking in the ruggedness usually associated with mountains and the term Black Hills is somewhat misleading in that respect.

The Black Hills were formed by a domical uplift at the end of the Cretaceous which on erosion exposed all of the Cretaceous and older formations down to the pre-Cambrian complex. Twenty-two formations are listed by Darton⁹ in the generalized columnar

² O'Harra, C. C. and Connolly, J. P.; *S. D. School of Mines, Bull.* 14, (1926).

³ O'Harra, C. C.; A bibliography of the geology and mining interests of the Black Hills region: *S. D. School of Mines Bull.* 11, (1917).

⁴ Darton, N. H., and Paige, Sidney; Central Black Hills: *Folio 219, United States Geological Survey* (1924).

⁵ O'Harra, C. C.; The Mineral wealth of the Black Hills: *S. D. School of Mines, Bull.* 6 (1902).

⁶ Darton, N. H.; Preliminary description of the geology and water resources of the southern half of the Black Hills: *U. S. Geol. Survey, 21st Ann. Rept.*, pt. 4, pp. 409-459 (1901).

Darton, N. H.; Geology and water resources of the northern portion of the Black Hills: *U. S. Geol. Survey, Prof. Paper* 65 (1909).

⁷ Irving, J. D., Emmons, S. F., and Jaggar, T. A.; Economic resources of the northern Black Hills: *U. S. Geol. Survey, Prof. Paper* 26 (1904).

⁸ Jaggar, T. A., and Howe, E.; The laccoliths of the Black Hills: *U. S. Geol. Survey, 21st Ann. Rept.*, pp. 163-307 (1901).

⁹ *U. S. Geol. Survey, Folio 219* (1924).

section. These embrace all periods except the Silurian and Devonian, although many periods are only partly represented.

Igneous rocks are abundant, the most important being the pre-Cambrian granite and pegmatites of the Harney Peak region and a great series of Tertiary porphyries which occur over a wide area in the northern part and form many well known masses, of which the Devil's Tower is especially well known. The variety of the exposed rocks accounts for the great number of minerals found in the region.

MINERALOGY

PREVIOUS WORK.—So many papers have been published on the minerals of the Black Hills that no attempt will be made to list them all, but the reader is referred to Dr. O'Harra's bibliography or the bibliography in Ziegler's bulletin. The comprehensive work by Ziegler¹⁰ deserves special note. It contains a complete list of minerals recognized up to that time with general descriptions of the properties, notes on localities, and special types found in the Black Hills. The writer has drawn freely on this and other publications for information. Unfortunately the copies of the bulletin are exhausted and it is necessary to refer to it in the libraries. The writer has been informed, however, that Professors O'Harra and Connolly hope to issue a revised edition within two years.

MINERALS.—Ziegler lists 182 minerals found in the Black Hills and immediately surrounding region. Many of these are comparatively rare and probably could not be found in any accessible openings. Many others would doubtless be found only by a very careful search. The list includes 7 native elements, 22 sulphides, tellurides and arsenides, 8 sulpho-salts, 7 haloids, 26 oxides, 13 carbonates, 65 silicates, 2 niobates and tantalates, 24 phosphates and arsenates, and 22 sulphates. A more varied group could scarcely be desired. Of Ziegler's list about 80 are reasonably easy to find or have been found in considerable amounts. By far the greater variety is found in the pegmatites surrounding the Harney Peak granite especially those near the village of Keystone. The mineralogist visiting the region should pay special attention to this interesting area.

¹⁰ Ziegler, V.; *The minerals of the Black Hills: S. D. School of Mines, Bull.* 10, 250 pages, 31 plates, 73 figures (1914).

LIST OF THE MORE COMMON MINERALS FOUND IN THE BLACK HILLS REGION.
(Those usually available are starred.)

actinolite*	dolomite*	opal*
aegirite*	epidote	orthoclase*
almandite	feldspar* (see var.)	phlogopite
albite*	ferberite	purpurite
alunite*	fluorite	pyrite*
amblygonite*	galena*	pyrolusite
andalusite*	garnet* (see var.)	pyrrhotite*
andesine	gold	quartz*
anglesite	glauconite	saponite
ankerite	graphite*	scheelite
apatite*	griphite	scorodite
aragonite	grossularite	serpentine
arsenopyrite*	gypsum*	siderite*
augite*	hematite*	smithsonite*
barite	hornblende*	sillimanite*
beryl*	huebnerite*	sphalerite*
biotite*	labradorite	spodumene*
bismuthinite	lepidolite*	stannite*
calcite*	loellingite*	staurolite*
cassiterite*	limonite*	struverite
cerargyrite	lithophillite*	talc
cerussite*	mica (see var.)	tantalite
chalcedony*	microcline*	topaz
chalcopyrite	magnetite*	tourmaline*
chlorite*	malachite*	triplite
columbite*	muscovite*	wolframite*
cuprocassiterite*	oligoclase	zircon*
cummingtonite*		

DEPOSITS.—The Harney Peak granite is apparently only the top of a large batholith and much of the main mass is pegmatitic. Extending outward into the schists in all directions are dikes and irregular masses of pegmatite. Some of these are several miles horizontally from the main granite mass. The most interesting and economically important are these masses in the schists. The area around the village of Keystone contains the greatest number of commercial deposits but at other places much of interest may be found. The rose quartz deposits near Custer serve as an example.

Some of the many deposits deserve a few details, either because of the great variety of minerals found or the unusual nature of particular minerals and their occurrence.

The Etta mine near Keystone is the most famous of the Harney Peak group due to the immense crystals of spodumene found

there. The largest crystal recorded was forty-two feet long, from three to six feet in diameter, and contained thirty-seven tons of spodumene. Many others nearly as large have been mined. These are without doubt the largest crystals of any mineral thus far discovered. The pegmatite is roughly oval in outline with diameters of 200 and 250 feet,¹¹ and shows a rude zoning with the main body of quartz, spodumene and feldspar surrounded by a finer grained aggregate of muscovite with quartz and feldspar. Normally the spodumene crystals are embedded in masses of milky quartz. Aside from the minerals noted above the following are more or less common: columbite-tantalite, lepidolite, apatite, beryl, lithiophilite, cassiterite, triphylite, and opal.

At least three other deposits near the Etta mine should be visited by those interested in mineralogy. About a thousand feet west of the Etta is a huge mass of pegmatite in which the Hugo mine has been excavated. This pegmatite also contained large spodumene crystals but neither as large nor as abundant as those in the Etta mine. The large masses of nearly pure microcline are notable. Large masses of amblygonite and considerable amounts of mica are important constituents. Extensive mining in the last three years has opened up many new features in this deposit. The large masses and crystals of black tourmaline in the mine and surrounding pegmatite are most remarkable. Similar masses of blue apatite are occasionally encountered. In general this pegmatite seems to be an irregular body, rather than a dike, with a base of schist which dips sharply northwest. Large inclusions of schist are encountered in mining. As in the other deposits the greatest segregations of mica occur near the contacts.

The Peerless mine is located on a high hill midway between the Etta mine and the village of Keystone. In some respects this deposit is more remarkable than the Etta. For variety of minerals and their relationship it is perhaps the best opening at present. Many of Hess' illustrations of replacement were derived from this deposit.¹² A single pseudomorph of an unusual nature consists of a crystal about one inch in diameter and perhaps three inches in length. This was originally beryl with the characteristic hexagonal

¹¹ Schwartz, G. M.; *Geology of the Etta spodumene mine, Black Hills, South Dakota; Econ. Geol.*, vol. 20, pp. 646-659 (1925).

¹² Hess, F. L.; *The natural history of pegmatites: Eng. and Min. Jour.-Press*, vol. 120, pp. 289-298 (1925).

form but now consists of an interior of quartz with a coating of small albite crystals. The mine is now producing mica, feldspar, beryl, amblygonite, columbite-tantalite, and lithiophilite. Cassiterite is common and large masses of a fine green micaceous mineral presumably vermiculite, are also common. Numerous rarer minerals are found, particularly apatite, tourmaline and so on.

Mr. Hesnard states that the active mining of the past three years indicates the deposit to be a shoot dipping northwest and that a rough stratification exists with mica, large masses of muscovite, and finer grained vermiculite and liebnerite with some quartz and feldspar near the base. Above this is a zone with amblygonite, quartz, beryl, etc. The top is mainly feldspar and quartz.

The Bob Ingersoll mine is located about two miles west of Keystone on a high hill along the valley of Battle Creek. The openings are somewhat above one another on three dikes or masses of pegmatite. The lower pit contains considerable amounts of spodumene, amblygonite, beryl, feldspar and mica with some columbite and cassiterite. The middle pit at present shows mainly beryl and amblygonite. The upper contains very large masses of pure lepidolite in the center with considerable amounts of beryl, amblygonite, mica, cassiterite and columbite. A large mass somewhat pipe like has yielded unusually large amounts of high grade amblygonite. As stated by O'Harra and Connolly¹³ the Ingersoll is particularly noted for its massive ledges of lepidolite and for the occurrence of what is probably the largest beryl crystal ever discovered. This is 46 inches in diameter and its full length has not been uncovered.

Other pegmatite deposits deserving special note are the Beryl Mica Lode, Climax, Everly, Wood Tin, New York, Crown, White Star, Pioneer Mountain, and Scott Rose Quartz.

The deposits of the Harney Peak region are the most interesting in the Black Hills from a mineralogic standpoint, but some of the deposits of the Northern Hills are not lacking in interest. A visit to the region would scarcely be complete without at least a short visit to the Homestake gold mine and the surrounding area. Perhaps the most interesting mineral, aside from the gold which is only rarely visible, is cummingtonite, a comparatively uncommon

¹³ *Op. cit.*, p. 95.

amphibole. Cumingtonite schist is an abundant lode rock. Common minerals include arsenopyrite, pyrrhotite, chlorite and quartz.

A number of other deposits might be mentioned as well as specific occurrences of minerals. A recent bulletin by Professor Connolly¹⁴ gives a great deal of information on the deposits of the Northern Hills. Those interested should refer to this and other papers cited above. A visit is necessary to even partly appreciate the mineralogic wealth of the Black Hills and the collector will not fail to find many interesting specimens.

A MINERAL RELATED TO SAMARSKITE FROM THE WOODCOX MINE, HYBLA, ONTARIO*

H. V. ELLSWORTH, *Ottawa, Canada.*

The Woodcox feldspar mine¹ (lot 17, con. VIII, Monteagle township, Hastings county, Ontario) was noteworthy because of the occurrence of large individual masses of radioactive minerals, sometimes reaching a weight of 100 pounds or more. These masses were crudely globular in form and in most cases consisted not of one mineral species only but of several, each individually quite distinct. The association generally was cyrtolite, columbite, and black and brown minerals of the complex titano-tantalo-columbate types, the radioactive minerals usually making up from 75 to 95 per cent of the total mass, with columbite next in order of abundance. Walker and Parsons² have described black and brown hatchettolite which probably occurred in this way. The mineral here described was part of a large mass which originally must have weighed at least 100 pounds. It consisted chiefly of a brown complex columbate, with some black mineral (the subject of this paper) and columbite. There appeared to be little or no cyrtolite in this case. The brown mineral appears to be a more altered phase of the black one. The latter was analyzed because it presumably would represent more nearly the original composition of the mineral and might be expected to be more favorable material for de-

¹⁴ Connolly, J. P.; Tertiary mineralization of the Northern Black Hills: *S. D. School of Mines, Bull.* 15, (1927).

* Published by Permission of the Director of the Geological Survey, Canada.

¹ *G. S. C. Summary Report, 1923, Part CI, page 12 et seq.*

² *Contributions to Canadian Mineralogy, 1923.*

termining the radioactive age ratio. The samples selected for analysis on microscopic examination appeared to be homogeneous and free from inclusions of any kind. The mineral is brilliant jet black en masse, brownish and isotropic in grains or sections under the microscope. The powder is grayish-brown and lustre is brilliant submetallic. Cleavage none, fracture subconchoidal. $H=6.5$, sp. gr.=4.738, and massive.

An analysis yielded the following results:—

CALCIOSAMARSKITE FROM THE WOODCOX MINE, HYBLA, ONTARIO

	Per Cent	Mol. Wt.	Bases	Acids
PbO.....	0.44	222	0.0018	
(Pb=0.41)				
UO ₂	9.00	270.2	0.0333	
UO ₃	1.67	286.2		0.0058
(U=9.32=10.99 U ₃ O ₈)				
ThO ₂	3.34	264	0.0127	
(Th=2.93×0.38=1.05U equiv.)				
(Ce,La,Di) ₂ O ₃	1.68	330	0.0051	
(Yt,Er) ₂ O ₃	11.38	251	0.0453	
(Average At. Wt.=101.5)				
FeO.....	0.21	72	0.0030	
Fe ₂ O ₃	7.67	159.7	0.0418	
MnO.....	0.04	70.9	0.0005	
Al ₂ O ₃	0.16	102.2	0.0015	
BeO.....	0.26	25.1	0.0104	
CaO.....	7.56	56	0.1350	
MgO.....	0.02	40.3	0.0005	
ZrO ₂	0.02	122.6		
SnO ₂	1.49	150.7		0.0099
TiO ₂	2.50	80.1		0.0325
Ta ₂ O ₅	2.54	443		0.0057
Cb ₂ O ₆	43.32	266.2		0.1627
SiO ₂	2.39	60.3		0.0396
H ₂ O-110°.....	.40			
H ₂ O+110°.....	3.24		0.2909	0.2562
He, etc., alkalis—not determined	—			
Sp. Gr.=4.738 at 25.50°	99.33			
Pb/U+0.38Th=0.04				

The analysis yields a very low lead ratio in agreement with Todd's results³ for hatchettolite from this mine. The high silica content is noteworthy and is unquestionably the result of alteration. The whole of the dike exposed by the workings has been

³ Walker and Parsons, *loc. cit.*

more or less shattered apparently chiefly, if not wholly, by the radio-active mineral masses and has been subjected to considerable alteration by surface waters. This mineral furnishes another instance of a Precambrian mineral with an abnormally low lead ratio associated with a high silica content, a point to which the writer has given some attention in earlier papers.

The mineral seems to be most nearly related to samarskite though containing very much more lime than has been previously found in samarskite. All the radioactive minerals found in the calcite-bearing pegmatites of the Haliburton-Bancroft area tend to be high in lime, doubtless because of the universal presence of dissolved calcium carbonate in the magmas of that area. Thus this mineral perhaps represents the type of samarskite produced by a magma rich in lime. Considering the term samarskite as embracing a group of minerals in which considerable percentage variations of the constituents may conceivably occur, due to isomorphous replacement, the mineral here described seems to represent the case where iron is partly replaced by lime, and the name *calciosamarskite* is suggested as a suitable designation for this variety.

The writer is indebted to Dr. E. T. Wherry for a discussion and opinion regarding the classification of this mineral. Dr. Wherry considers that "as we know so little as to the constitution of the complex columbate minerals the presence of a larger amount of calcium as compared with the original samarskite is not an adequate basis for classifying the mineral as a new species. If it could be demonstrated that the high lime content of this mineral represents a definite isomorphous replacement of some constituent of the original samarskite, then it might well be considered a distinct species, the end member of an isomorphous group analogous with the garnet or feldspar groups. Since, however, the role of the lime, iron oxides, etc., in samarskite cannot be clearly made out I would favor terming it calciferous samarskite."

A mineral similar to this in composition occurring at Parry Sound is described in the following article of this Journal.

A MINERAL RELATED TO SAMARSKITE
FROM PARRY SOUND, ONTARIOH. V. ELLSWORTH,* *Ottawa, Canada.*

The area immediately to the east of Blackstone Lake, Parry Sound district, contains numerous pegmatite dikes which carry an interesting assemblage of rare minerals. One of the most productive of these dikes occurs on the line between lots 9 and 10, con. IX, Conger township, 13 miles by rail south east of Parry Sound town. This dike was first prospected for muscovite and later several fairly rich pockets of uraninite crystals were exposed by a comparatively small amount of work. Along with the uraninite is a small amount of the mineral here described which often occurs within a few inches of the uraninite crystals, both apparently having crystallized contemporaneously under identical conditions. A remarkable carbon mineral, which will be described in another paper under the name of thucholite, is sometimes very intimately associated with both uraninite and samarskite. Crystals of uraninite completely enclosed in this carbon have been found and the samarskite is also often partly enclosed by or in contact with the carbon mineral. Nodules of the carbon are usually intergrown with altered grayish material in part massive but showing some zircon-like crystals, which an analysis indicates to be a mixture of intergrowth of cyrtolite and a phosphate. Allanite also occurs in these dikes in small quantity but is not closely associated with the minerals just mentioned, being confined chiefly to the margins; so far as observed by the writer. The allanite is only slightly radioactive. Other dikes in the neighborhood have yielded these same minerals in smaller quantities and from one which was worked for feldspar some fine specimens of columbite were obtained.

The mineral which is the subject of this paper for convenience will be called *calciosamarskite*, though its proper classification is somewhat uncertain. It is much less abundant than uraninite, being in fact rare, in the dike mentioned above so far as exposed up to the present, though what appears to be the same mineral occurs much more abundantly in another dike a few hundred feet distant in which uraninite is apparently absent or at least was not seen. The *calciosamarskite* from the uraninite-bearing dike was

* Published by permission of the Director, Geological Survey of Canada.

however, particularly interesting because it afforded an opportunity to compare the lead ratios of the two minerals occurring only a few inches apart under identical conditions in the same dike. The complex columbate minerals frequently yield a low lead ratio, compared with uraninites from rocks of apparently identical age and the writer has ascribed this to alteration but as the two minerals rarely occur together there was of course always the possibility that the complex minerals really were younger than the uraninites. The analysis of this particular complex columbate shows conclusively that such minerals may sometimes be of no value whatever as geological age indicators. The writer's experience with Canadian minerals of this type indicates that when they contain more than a very small amount of SiO_2 the age ratio must be regarded with suspicion as being probably too low.

The calciosamaraskite is black en masse, brownish and isotropic in thin grains or sections under the microscope. Other properties are: powder, brownish gray; cleavage none; fracture irregular; lustre submetallic. Hardness 6.5. Sp. Gr. = 4.485. It occurs occasionally as rough, square prisms up to $\frac{1}{2}$ inch in diameter by an inch in length. It is often associated with thucholite and cyrtolite-phosphate intergrowths. Usually it occurs in feldspar near or with clusters of biotite.

The material selected for analysis was the best available, but was slightly contaminated by thucholite and cyrtolite-phosphate.

The deficiency in the summation of the analysis is largely due to the presence of carbon (from thucholite) which was not determined. The carbon also rendered it impossible to determine UO_2 and FeO with certainty. The very low lead ratio compared with that of unraninite¹ from the same dike (0.15) was so startling that several determinations were made all of which yielded practically the same result, the latest and most careful work yielding merely a trifle less lead and slightly more uranium than the earlier determinations.

The proper classification of this mineral is somewhat uncertain but it seems to be rather closely related to a mineral² from Hybla described by the writer as a variety of samarskite, under the name calciosamaraskite.

¹ *Am. Journ. Science*, Vol. IX, February, 1925.

² A Mineral related to Samarskite from the Woodcox Mine, Hybla, Ontario. This Journal, preceding article.

CALCIOSAMARSKITE FROM PARRY SOUND, ONTARIO

	Per Cent	Mol. Wt.	Bases	Acids
PbO.....	0.38	222	0.0017	
(Pb=0.35)				
¹ UO ₂ Not determined perhaps about	10.0	270.2	0.0370	
¹ UO ₃ Not determined perhaps about	3.06	286.2		0.0107
(U=11.35=13.38 U ₃ O ₈).....	13.38			
ThO ₂	2.16	264	0.0082	
(Th=1.90×0.38=0.72U equiv.)				
(Ce, La, Di) ₂ O ₃	4.04	330	0.0123	
(Yt, Er) ₂ O ₃	10.71	250	0.0428	
¹ FeO }.....	3.01	159.7	0.0188	
Fe ₂ O ₃ }				
MnO.....	0.23	70.9	0.0032	
Al ₂ O ₃	0.65	102.2	0.0063	
BeO.....	0.49	25.1	0.0296	
CaO.....	4.76	56	0.0850	
MgO.....	0.14	40.3	0.0034	
ZrO ₂	0.24	122.6		0.0019
SnO ₂	0.48	150.7		0.0032
TiO ₂	1.43	80.1		0.0178
Ta ₂ O ₆	4.86	443		0.0110
Cb ₂ O ₆	43.50	266.2		0.1634
SiO ₂	1.92	60.3		0.0318
H ₂ O-110°.....	0.68			
H ₂ O+110°.....	5.76		0.2483	0.2398
He, etc. alkalis—not determined				
C.....Present	98.82			
Sp. Gr.=4.485 at 24.00°				
Pb/U+0.38 Th=0.03				

¹ UO₂, UO₃, and FeO not determinable because of the presence of carbon from thucholite.

Dr. Wherry, who has very kindly given the writer the benefit of his opinion on this point, thinks that both are related to samarskite especially if the ratios of the various oxides are compared separately with those of the North Carolina samarskite. The writer, while agreeing that they are of the samarskite type, believes that the high CaO content of these two minerals (from Parry Sound and Hybla) represents a definite variation from the usual samarskite which might well be recognized by the adoption of the name *calciosamarskite* for minerals of this composition.

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, December, 1, 1927.

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with the president, Mr. Clay, presiding. Thirty members and twelve visitors were present.

Messrs. J. G. Denton and J. M. Poli were elected to membership and W. Parrish and J. Gottshalk to junior membership.

The speaker of the evening was Dr. D. H. Kabajian of the University of Pennsylvania who addressed the Society on "*Luminescence in Minerals due to Radioactivity*." Three types of luminescence were described: (1) that due to molecular forces and dependent on the chemical composition of the substance and not greatly affected by temperature, (2) the luminescence of radium salts when heated, (3) the luminescence of substances that have absorbed energy by exposure to radium, when heated (thermoluminescence). Spectacular lecture demonstrations of each of the above types were given: the luminescence of activated zinc sulfide, of heated radium salts, calcite, fluorite, gypsum and of artificial gems upon heating after exposure to radium.

Trips were reported by Messrs. Hoadley, Biernbaum, Cienkowski, Vanartsdalen, Hallowell and Trudell.

A paper entitled *Chromrutile, a new mineral from California*, by Samuel G. Gordon and Earl V. Shannon, was read by title. The mineral occurs as small, brilliant black crystals, with k  mmererite, on specimens of chromite from the Red Ledge Mine, in the Washington district of Nevada Co., California. An analysis by Shannon gave: SiO₂ 5.51, TiO₂ 69.71, Al₂O₃ 0.57, Fe₂O₃ 0.80, Cr₂O₃ 16.61, CaO 0.76, MgO 5.52, ignition 1.48; sum 100.96; hence the name *Chromrutile*. The mineral is distinct from rutile, however, crystallographically; the crystals have the symmetry of the tetragonal bipyramidal class (scheelite type), and $\rho_0 = 0.611$; $\rho = 40^\circ 50'$.

F. A. CAJORI, *Secretary*.

THE MINERALOGICAL SOCIETY (ENGLAND)

Mineralogical Society (Anniversary Meeting):—November 1, 1927. Dr. G. T. Prior, President, in the chair.

L. J. SPENCER: *Specific gravities of minerals: an index of some recent determinations*.—Specific gravity as determined by heavy liquids affords a convenient first-aid in the determination of minerals. 2277 determined values collected from the recent mineralogical literature are arranged numerically, and an alphabetical index of mineral names gives the minimum and maximum values for each mineral.

L. J. SPENCER: *South African occurrences of willemite. Fluorescence of willemite and some other zinc minerals in ultra-violet rays*.—Willemite is described from Broken Hill, and two other localities in Northern Rhodesia where it appears to be of abundant occurrence, and from Guchab in South-West Africa. Unlike the willemite of Franklin Furnace, New Jersey, some of these do not fluoresce in ultra-violet rays. Fluorescence is not a constant and essential character of a mineral species, and it evidently depends on the presence of admixed impurities.

T. V. M. RAO: *A Study of Bauxite*.—Specimens of laterites from India, Gold

Coast and other countries were described and the occurrence in them of bauxite and several accessory minerals was pointed out. It was shown that laterite was a rock largely composed of the mineral bauxite, which had a definite composition corresponding to the formula $\text{Al}_2\text{O}_3, 2\text{H}_2\text{O}$. Details of an experiment to trace the process of laterisation were also given.

P. K. GHOSH: *Biotite bearing greenstones*.—The biotite constituent, which has so far been ascribed to the metamorphic action of the Armorican granite on the pre-existing greenstone, is proved to be the undigested and residual part of the slate fragments stoped by the greenstone magma at the time of its intrusion. Rhyolitic pumice is noted for the first time in this region and its mineralogical characters are described.

W. CAMPBELL SMITH, *General Secretary*

NOTES AND NEWS

MINERALS IN EASTERN EXPOSURES OF THE LOCKPORT IN NEW YORK STATE

JOSEPH W. MONAHAN, *New York City*.

This note deals with certain mineral localities in the Lockport group of Oneida county, New York. The minerals occurring there, in order of abundance, are dolomite, calcite, celestite, sphalerite, quartz, and pyrite. A reference in Dana¹ to the occurrence of gypsum near Starkville, in Herkimer county, probably also refers to an outcrop of the Lockport.

At Sherrill, in outcrops along the Sconondoa Creek, dolomite is extremely abundant, calcite and celestite fairly abundant, quartz, sphalerite, and pyrite, rare. The exposure here is composed of eighteen feet of black shale interbedded with stromatoporoid reef dolomite and overlain by twelve feet of thin bedded, brownish dolomite. A westerly monoclin dip keeps the principal reef above the surface for about half a mile.

Along the growth surfaces of the stromatoporoid reefs, irregular geodes have developed, decidedly flattened, and curved parallel to the surfaces. They are often a foot in longest dimension but never more than three inches in thickness. In the overlying dolomite the geodes are of a roughly spherical form, up to six inches in diameter. The occurrence of geodes in the dolomite is, however, rather rare as contrasted with their notable abundance in the reefs.

Dolomite lines all of the geodes of the reefs, and occurs as well in those of the dolomite beds. The unit rhombohedron alone was observed. The crystals are small, usually one third to two-thirds of an inch on the long diagonal.

Calcite occurs in the reef geodes in moderate amount as dog-tooth scalenohedra three-fourths of an inch to an inch in length. In the geodes of the upper beds both scalenohedra and nail-head crystals occur. Both dolomite and calcite show the presence of strontium.

Celestite occurs in the reef geodes having crystallized with the calcite, or a little later. It forms small, yellowish, poorly developed, acicular crystals with radiating structure on the surfaces of the dolomite crystals. In the geodes of the upper beds celestite is more common. Here it forms comb-like and radiating masses of white or bluish tabular crystals. Half inch crystals are common, and in the Root collec-

¹ Dana, J. D.; *System of Mineralogy*, 6th edition, p. 1063 (1914).

tion of Hamilton College there is an aggregate of crystals, apparently from this locality, whose individuals are two and one half inches long and one half inch thick. The faces observed are: (001), (102), (011), and (110). Celestite also occurs in the geodes of the upper beds as white, fibrous masses, with an admixture of calcite.

Sphalerite is not common at Sherrill, occurring only in the upper beds as scattered, anhedral grains. In more easterly localities in Oneida county, however, it is more common. The citations of Beck² of regions near Rome, Vernon, and at Clinton, probably refer to Lockport localities. The principal occurrence of the sphalerite is as cleavable, red-brown masses, with calcite, filling hollows in a breccia of stromatoporoid fragments, the so-called 'horse-bone' conglomerate. It more rarely occurs in developed crystals in the reef itself. Several well developed crystals are in the Root Collection, but their forms have not been determined.

The occurrence of pyrite was observed only at Sherrill, and even here only in very small quantities. It forms minute veinlets, less than an eighth of an inch in thickness, and occasionally small, irregular masses, in the body of the reef. No connection was observed between these masses and veinlets and the geodes of the reefs.

The present officers of the Newark Mineralogical Club are: President, D. T. O'Connell; Vice President, J. A. Grenzig; Secretary, Wm. H. Broadwell. Meetings are held the first Sunday of each month at the Newark Technical School, 367 High Street. The ninety third regular meeting held December 4 was devoted to a general discussion of the subject of "Fluorescence."

At the annual general meeting of the Mineralogical Society, England, held on November 1, Dr. G. T. Prior, keeper of the department of minerals in the British Museum, was elected president.

The department of mineralogy and petrography at Harvard University was able through the Holden Travel Fund to send out several parties during the past summer. Harry Berman accompanied Dr. W. F. Foshag of the U.S. National Museum to Mexico; Professor Larsen mapped the geology of a region near Elsinore, California; and Professor Palache and L. W. Lewis visited a number of mines at Cobalt and Sydenham, Canada.

Dr. Lea McI. Luquer has been appointed research associate in optical mineralogy at the American Museum of Natural History.

Professor M. A. Lacroix, professor of mineralogy at the University of Paris, has been made a foreign member of the Stockholm Academy of Sciences.

Lady Lyell of Kinnordy has presented to the department of geology of the University of Edinburgh valuable collections of minerals, rocks and fossils, together with cabinets for keeping them. In addition Lady Lyell has given many geological books and papers of historical interest from scientific workers of note to the late Sir Charles Lyell.

* Beck, L. C.; *Natural History of New York*, Part 3, Mineralogy, p. 410 (1842).

NEW MINERAL NAMES

Telegdite

LÁSZLÓ ZECHMEISTER AND VERA VRABÉLY: Über Telegdit, ein fossiles Harz aus Siebenbürgen. (Telegdite, a fossil resin from Siebenbürgen). *Centr. Min.*, 1927, pp. 287-290.

NAME: In honor of Priv. Doz. K. v. Roth-*Telegd*, who furnished the material.

CHEMICAL PROPERTIES: A resin: C 76.93, H 10.17, S 1.73, O (by difference) 11.17. Partially soluble in absolute alcohol (27%), ether (33%), chloroform (63%). Insoluble in epichlorhydrin and cajeput oil. Upon heating gives off H_2S .

PHYSICAL AND OPTICAL PROPERTIES: Color honey yellow to yellow brown. Streak yellow. Upon rubbing becomes negatively electric. $n_D = 1.5416$. Sp. Gr. = 1.09. $H = 2.5$.

OCCURRENCE: Found in quartz sand and marls in masses up to the size of a nut at Szászcső, Szeben, Siebenbürgen.

W. F. FOSHAG

Ajkaite

LÁSZLÓ ZECHMEISTER AND VERA VRABÉLY: Notiz über Ajkaite (ein organisches Mineral aus Ungarn. Ajkaite, an organic mineral from Hungary), *Ber. d. d. Chem. Gesell.*, 69, 1426-1428 (1926).

NAME: From the locality *Ajka*, Hungary.

CHEMICAL PROPERTIES: A fossil resin. Analysis: Light—C 80.38, H 11.00, O 7.20, S 1.41. Dark—C 79.01, H 9.89, O 9.61, S 1.49. Free of ash, N, Cl. Upon heating evolves H_2S . Sinters at 180° , becomes soft at 205° . Fuses to a honey like liquid. Burns with a sooty flame and resinous smell. Gives no succinic acid upon distillation. Insoluble in hot absolute alcohol, ether or carbon bisulfide; in pyridine or chloroform 4%. Slowly but completely soluble in cajeput oil. Reacts with nitric acid.

PHYSICAL PROPERTIES: Amorphous. Transparent. Color pale yellow to dark reddish brown. Becomes negatively charged upon rubbing. Sp. Gr. = 1.05-1.06. $H = 2.5$. $n_D = 1.5412$. Weakly birefracting.

OCCURRENCE: Found in the brown coal beds at Ajka in Hungary.

W. F. F.

Boehmite

JACQUES DE LAPPARENT: L'Alumine hydratée des bauxites. (The hydrated alumina of bauxite). *Compt. Rend.*, 184, pp. 1661-1662, 1927.

NAME: In honor of H. *Boehm* who studied some bauxites by X-rays.

CRYSTALLOGRAPHIC PROPERTIES: Microscopic orthorhombic plates with the forms m (110) and c (001). Prism angle 63° .

CHEMICAL PROPERTIES: Hydrated aluminum hydrate, $Al_2O_3 \cdot H_2O$. No analysis given but the composition deduced from its X-ray similarity to lepidocrocite, $Fe_2O_3 \cdot H_2O$.

PHYSICAL AND OPTICAL PROPERTIES: Cleavage good parallel to the base. Plane of the optic axes parallel to the base with Z = macrodiagonal of the prism. Birefringence 0.020. Mean index of refraction slightly higher than that of gibbsite.

OCCURRENCE: Well developed in the bauxites of the Provinces of Ariège (Pérlille, Cadarcet) and Var (Recoux).

W. F. F.